Hamill, John Molyneaux
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REPORTS

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PUBLIC HEALTH AND MEDICAL SUBJECTS.

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by

J. M. HAMILL, O.B.E., M.D., D.Sc.,

A Medical Officer of the Ministry of Health.

MINISTRY OF HEALTH.

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To the Right Hon. Sir Alfred Mond, Bart., M.P.,
Minister of Health.

Sir,

I beg to present the following Report on Diet in relation to Normal Nutrition, by Dr. J. M. Hamill, one of the Medical Officers of the Ministry.

The sound nutrition of the individual and the community is the foundation of the public health. Though not wholly dependent upon the amount or quality of the food consumed, it is obvious that the food of a people is of primary importance in nutrition; other factors are effective mastication, the proper use of the dietary selected, and the capacity of the body to assimilate and make full use of the food consumed, which capacity is largely determined by a sufficiency of exercise, rest and fresh air. Whilst these important matters should not be neglected, the primary necessity is of course a satisfactory diet, and that is the subject of the present Memorandum.

Requests have been addressed to the Ministry for a concise summary of our present knowledge of dietetics. Authoritative information is desired by medical officers of health, medical practitioners, and teachers and lecturers, as to the extent to which our practical knowledge of this subject has been modified by recent discoveries, particularly in regard to accessory food constituents, which have aroused widespread interest. The relations of these discoveries to the older established facts of human nutrition have not hitherto been brought to general notice, with the result that incorrect or unbalanced conceptions have obtained currency as to the significance of vitamins in nutritive dietaries.

It is probably true to say that much ill-health, and much of the physical impairment, which obviously abounds, is due to dietetic deficiency and the improper selection and use of foods. The object of this Report is to review the present position and to show why, and in what way, the new facts respecting vitamins should be woven into the general fabric of our practical knowledge of dietetics, a subject in which happily the public are taking ever-increasing interest. Its purpose is not, however, academical, or of theoretical concern only. It is designed to afford guidance to the reader as to the principles which govern the proper selection of the articles of food composing his dietary, in respect both of economical expenditure and the full maintenance of his bodily health.

The Ministry have in contemplation the issue of one or more leaflets, which may serve as guidance to Local Authorities in any popular instruction in this subject which they deem expedient.

I have the honour to be,
Sir,
Your obedient Servant,

George Newman

Whitehall, September, 1921.

DIET IN RELATION TO NORMAL NUTRITION.

It is now generally recognised that a suitable food supply and its rational utilisation are of cardinal importance in maintaining the health and efficiency of the community. The first official report issued on the physical examination of recruits during the late war has revealed the fact that a substantial proportion of the population of this country suffers from physical defects which are largely traceable to abnormal or arrested development during the period of life when growth is most rapid. Every addition to knowledge indicates more and more clearly that physical defects of this kind have their origin largely in improper nutrition resulting from deficient and unsuitable dietaries during early life. The body when properly fed and well nourished has extraordinary powers of resistance to disease and adverse circumstances. Breast-fed infants of well nourished mothers can withstand conditions of life that would be fatal to others not so well fed. The children of crofters, though often living in overcrowded hovels, are remarkably free from rickets, whereas children living in better surroundings but improperly fed fall readier victims to this disorder of nutrition. The incidence of tuberculosis in a community appears to be closely correlated with the food supply; it diminishes when the food supply is ample and suitable, and increases when for one reason or other food is difficult to obtain and the quantity and quality of the diet become inadequate. Troops can withstand great hardships if their rations are ample and suited to their needs, and the ravages of infective diseases such as typhus are especially severe amongst those whose resistance has been impaired by lack of proper food. During the middle ages in this country harvests failed periodically, famine ensued and was usually accompanied or followed by outbreaks of infectious diseases. The correlation was well understood at the time and has survived in the phrase "famine and pestilence."

Sufficient and suitable food is therefore the first essential in building up and maintaining the physique and stamina of the nation. Good environment and other favourable conditions are adjuvant and important, but unless attention is given to the basic factor of nutrition, efforts in these directions will be largely shorn of their value.

It is, however, by no means a simple matter to say what is sufficient and suitable food, or when a diet may be regarded as satisfactory. A very large variety of food-stuffs is ordinarily available for consumption, and it is quite possible to prepare from these a diet which will be palatable or even luxurious but which is inadequate from the point of view of satisfactory nutrition; conversely, a diet may be constructed from simple and relatively few food-stuffs which so far as present knowledge goes may be regarded as meeting essential nutritive requirements.

During the past few years much attention and research has been devoted to dietetic problems, and valuable information

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has been obtained regarding the principles which underlie nutrition. So far only the fringe of the subject has been touched, and much yet remains to be discovered. The outlook, however, is promising, and perhaps on this account in various quarters undue stress has been laid on certain aspects of the subject, or too much has been anticipated and deductions have been made and conclusions arrived at which cannot be justified in the light of work so far accomplished.

It would be obviously impracticable to review the whole subject of nutrition within any reasonable compass, and no useful purpose would be served by the attempt, but in what follows an endeavour has been made to present a short summary of certain salient features in regard to present-day knowledge of dietetics in so far as they appear to have a practical bearing upon the question of nutrition.

1. The Nature of the Nutritive Constituents of Food.

For ordinary purposes food may be regarded as anything which taken into the body is capable of supplying material for growth and the repair of waste or for furnishing energy for bodily heat and work. Materials in large variety are available as foods, and contain substances which can be allocated to one or more of certain comprehensive chemical categories or groups. The chief of these groups are the proteins, the carbohydrates and the fats, certain mineral substances such as calcium, sodium, potassium, iron, &c., and in addition a class of substances of which little is known except that their presence or absence in a particular food-stuff is inferred from the effects produced on nutrition by the administration of the food-stuff in question. To this class of substances the terms "accessory food factors" or "vitamins" have been provisionally applied.

It is beyond the scope of this memorandum to describe in detail the chemical and other characteristics of the three great classes of organic food-stuffs or "proximate principles" as they are sometimes called, viz., the proteins, carbohydrates and fats. Information on these points can readily be obtained from various works dealing with the subject.*

2. Energy Requirements of the Body.

The repair of waste and the supply of material for growth of the body account for only a fraction of the total daily intake of food. This fraction varies somewhat with age; it is naturally larger during the period of life when growth is most rapid. In addition the body requires energy in order to perform muscular work and to produce heat to maintain the temperature of the body at its normal level (98·4° F.), and this energy is derived from the proximate principles of food, the proteins, carbohydrates and fats.

* *See* "Monographs on Biochemistry," published by Longmans, Green & Co.

It is convenient and usual in questions of nutrition to measure energy in terms of heat production since work is convertible into heat and may be measured in these terms. The unit of quantity of heat is termed a calorie and is the amount of heat required to raise the temperature of one gram of water through one degree Centigrade (actually from 15° C. to 16° C.). In nutrition the amount of energy required is so great that inconveniently large numbers would be required to express it in terms of calories, consequently the kilocalorie or large calorie is used; this unit is 1,000 calories and represents the amount of heat necessary to raise one kilogram of water from 15° C. to 16°. C. In dietetics the term Calorie is frequently used for shortness instead of the term kilocalorie and is spelt with a capital initial letter to indicate that it represents the larger of the two heat units.

The amount of energy required by the body has been the subject of very extensive investigation; it naturally depends upon a variety of circumstances, such as the size of the individual, the amount of physical work done, and the loss of heat from the body, which in turn is affected by such factors as surrounding temperature, amount of clothing, &c. The following are approximate daily energy requirements expressed in Calories for different classes of workers as estimated by Atwater.*

	Energy Value in Calories.
Man without muscular work - - -	2,700
Man with light muscular work - - -	3,000
Man with moderate muscular work - -	3,500
Man with hard muscular work - - -	4,500

It is obvious that size and weight of the body must influence its energy needs and these factors must be taken into account in assessing energy requirements. Rubner gives the following data which indicate the energy requirements of men of various weights whilst doing light work† :—

Weight, in kilograms.	Total Calories.	Calories per kilogram.
80 (12 st. 8 lb.)	2,864	35·8
70 (11 st. 0 lb.)	2,631	37·6
60 (9 st. 6 lb.)	2,368	39·5
50 (7 st. 12 lb.)	2,102	42·0
40 (6 st. 4 lb.)	1,810	45·2

It will be noticed that although the heavier men require a larger absolute amount of energy, the amount of energy per kilogram of weight which they need is less than in the case of lighter men. The area of the surface of the body and conse-

* U.S. Dept. of Agriculture (Office of Experiment Stations) Bulletin No. 21. 1895. *See also* amplified table, Bull. No. 84 (1900).

† Rubner: von Leyden's "Handbuch der Ernährungstherapie." 1903. Bd. 1. p. 153.

quently the amount of heat lost from it is relatively greater in small men than in large men and to meet this loss a relatively greater supply of energy is necessary.

The Food (War) Committee of the Royal Society has devoted considerable attention to the question of energy requirements, and on the basis of certain experiments* provisionally adopted the following scale† :—

Occupation.	Food Requirements.
Tailor	2,750 Calories.
Bookbinder	3,100 ,,
Shoemaker	3,150 ,,
Metal Worker	3,500 ,,
Painter	3,600 ,,
Carpenter	3,500 ,,
Stone Mason	4,850 ,,
Woodcutter	5,500 ,,

Attention was drawn to the scanty experimental data available for framing these estimates and the consequent need of caution in using them.

The usual estimate of the energy requirements of a woman as compared with a man is about four-fifths of the amount of the man's requirements. Obviously this is a general or average estimate and it may be exceeded in particular instances depending upon environment and occupation.

In children a computation of energy requirements is rendered more difficult by two factors. In the first place growth and metabolism are more active than in the adult, and secondly whilst children do not perform muscular work which is easily measurable they are in a constant state of muscular activity which is of great value for healthy development. The degree of this activity seems to depend upon the amount of food taken; activity declines if food is withheld or diminished.

In the following table are given the net energy requirements of children compared with the average man and woman, together with the relative requirements of each class expressed as co-efficients.

——	Energy Requirements, in Calories.	Coefficients.
Average man	3,000	1·0
Average woman	2,500	0·83
Children 0–6 years (both sexes)	1,500	0·5
Children 6–10 years (both sexes)	2,100	0·7
Children 10–14 years (both sexes)	2,500	0·83
Females, 14 years and upwards	2,500	0·83
Males, 14 years and upwards	3,000	1·0

* Becker and Hämäläinen: Skand. Archiv. für Physiologie *31*, p. 198, 1914.

† Report on the Food Requirements of Man, by the Food (War) Committee, Royal Society, March 1919.

The caloric values given represent the actual energy output of the individual; to meet this output the food must supply the same amount of utilisable energy. This depends upon the proportion of the food which is actually digested and assimilated, and since the loss due to incomplete digestion is generally taken to be about 10 per cent. the actual energy value of the food consumed should be about 10 per cent. greater than the energy requirements of the body. This adjustment has been made in the following table which gives the approximate energy value of the food required.

	Calories.
Children, 0–6 years - - - - -	1,650
,, 6–10 ,, - - - - -	2,300
,, 10–14 ,, - - - - -	2,750
Females, 14 years and upwards - - -	2,750
Males, 14 ,, ,, - - -	3,300

Now the energy requirements of the body can only be met by the energy supplied in food, and it follows that if the body is to maintain weight the amount of food ingested must be sufficient to furnish energy requirements. In any attempt therefore to estimate the sufficiency of a diet the amount of energy which it will supply must be ascertained since no diet which does not furnish enough energy to meet the requirements of the body can be regarded as adequate.

As already stated the energy of food is derived from its three "proximate principles" or great classes of organic food-stuff constituents, the proteins, carbohydrates and fats; it is therefore important to know what amount of energy these substances are capable of yielding. Much work has been done on this subject, and the following "standard values" which have been widely used throughout the world in determining the energy value of a mixed diet may be taken as sufficiently accurate for practical purposes :—

1 gram of protein will furnish 4·1 Calories.
1 ,, ,, fat ,, ,, 9·3 ,,
1 ,, ,, carbohydrates ,, 4·1 ,,

When the composition of any article of food in regard to its protein, fat and carbohydrate content has been ascertained by analysis it is an easy matter to determine by simple calculation from the foregoing standard values the amount of energy which any given quantity of the food-stuff in question is capable of supplying. Very commonly the amount of energy available is expressed in terms of Calories per pound or sometimes per kilogram of food material. Atwater* has published tables in which the composition and energy values of a large number of

* U.S. Department of Agriculture (Office of Experiment Stations), Bulletin No 28. 1899.

different foods in ordinary consumption in the United States are set forth. Recently Plimmer* has compiled similar tables for food materials in use in this country, and in Appendix 1 an extract from these tables has been made in which the composition and energy values of some of the commoner food stuffs are included.

On reference to Plimmer's tables it will be noticed that wide ranges of energy values are found in certain categories of similar food materials such as meat and fish. In the case of meat these diversities are due to the different composition of meat from various carcases or from different parts of the same carcase and can in the main be ascribed to the different proportions of fat which the specified articles contain. Similarly fish containing much fat or oil, such as salmon, herring or mackerel, have a higher energy value than white fish such as cod, flounder or haddock. On the other hand certain classes of food show a close similarity in energy value, for instance, most of the cereals and pulses possess an energy value in the neighbourhood of 1,600 Calories per pound.

An example of a typical diet in which the energy value of each item has been calculated from tables of energy values is given in Appendix 2.

The amount of energy in food which can be purchased for a given sum of money, for instance, a penny, affords a useful measure of the money value of food so far as energy supply is concerned. The energy value obtainable for a penny can be arrived at by dividing the caloric value per pound of any article of food by its price in pence per pound.

3. The Relative Proportions of the "Proximate Principles" in a Diet.

Although each of the proximate principles of food is capable of supplying energy to the body it is not practicable (for reasons which will be evident later when the functions of each of the proximate principles are considered in more detail) to rely upon any one of them exclusively as a source of energy. Apart from the mere supply of energy each of the three great classes of food-stuffs has important duties to perform which require the presence of each of them in any diet which is to be regarded as satisfactory for nutrition.

A very large amount of work has been done in an endeavour to ascertain what are the most suitable proportions in which the proximate principles should be present in a diet supplying an adequate amount of energy. Much of this work has been statistical in nature, that is to say, conclusions as to requirements have been deduced from the examination of the customary

* "Analyses and Energy Values of Foods," by R. H. A. Plimmer, published by H.M. Stationery Office, 1921.

diets of various classes of people. In the following table the conclusions of Voit, Rubner and Atwater who have devoted special attention to this subject are summarised.

Standard Dietaries for a Man of 70 Kilograms (Weights in Grams).

——	Voit.	Rubner.	Atwater.
LIGHT WORK—			
Protein -	—	123	100
Fat	—	46	*
Carbohydrates	—	377	*
Energy value (Calories) -	—	2,445	2,700
MEDIUM WORK—			
Protein -	118	127	125
Fat	56	52	*
Carbohydrates	500	509	*
Energy value (Calories) -	3,055	2,868	3,400
HARD WORK—			
Protein -	145	165	150
Fat	100	70	*
Carbohydrates	500	565	*
Energy value (Calories) -	3,574	3,362	4,150

As might be expected, the results obtained by these investigators are not in strict accordance. Divergencies are noticeable in the amount of protein and also in the proportion of carbohydrates and fats and, in the table in which Atwater's conclusions are given, no attempt is made to differentiate between carbohydrates and fats so long as sufficient is supplied to ensure the daily energy requirements. In point of fact the proportions of the proximate principles in a diet in individual cases may and do differ appreciably from these standards without affecting the nutritional value of the diet, if the total energy supplied is adequate. Much attention has been devoted to ascertaining the significance in nutrition of the proximate principles of food and the limits within which they may vary in a diet without impairing the value of the diet for nutritional purposes. The investigation of this subject presents great difficulties, and the power of the body to adapt itself within wide limits to diets varying greatly in composition adds considerably to the complexity of the problem. The salient features however which emerge from the mass of work which has been done on the subject may be succinctly stated in general terms.

Proteins.

The proteins are complicated nitrogenous substances upon which the body relies for its supply of nitrogen necessary for life and growth or in other words for the maintenance of meta-

* Carbohydrates and fats to make up the required energy value.

bolism.* Proteins therefore are essential constituents of all dietaries. Proteins are well known as the chief solid constituent of flesh (meat) but they are present in the tissues of all animals and vegetables, and such of these as are used for food are a source of supply of protein. The chief functions of proteins are to supply material required for the repair of waste of the tissues of the body and for their growth. In addition, of course, the protein consumed and metabolised in the body yields energy, but in an ordinary mixed diet containing a liberal amount of carbohydrate no appreciable amount of the energy of the protein is utilised in the performance of muscular work. This does not mean that protein is incapable of furnishing the energy for muscular work; in the absence of carbohydrate and fat, it is possible to obtain the energy for bodily needs from protein alone, but in the human body it would not be practicable to rely on protein for this purpose since very large quantities would be required which, even if they could be consumed, would put an excessive strain upon the digestive and excretory organs. The daily requirements of protein are not therefore a function of the daily output of muscular work as is the case in respect of energy requirements, which are in the main derived from fats and carbohydrates, and the question as to how much protein a dietary should contain requires consideration along other and different lines.

The conclusions reached by Voit, Rubner and Atwater as to the amounts of protein needed were to a large extent based upon observations of the quantities actually consumed by various persons, but it by no means follows that the values arrived at represent the actual physiological needs. The protein contents of the dietaries investigated depend on the nature of the food consumed by the classes under observation and this in its turn is largely determined by a variety of considerations such as the kind of food available, personal likes and national custom, climate, work and the purchasing power of the individual.

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* Metabolism may be defined briefly as the chemical changes which occur in the tissues of a living organism. Metabolism is a concomitant of all life and growth, and is the source of the energy liberated in the body for the purposes of work and production of heat. It is sometimes convenient to regard these chemical changes as of two types: (1) in which simple chemical substances are built up or synthetized into more complex substances; and (2) in which complex chemical substances are broken down into simpler substances. To the former the term *anabolism*, and to the the latter the term *katabolism*, is applied. In the building up of the body tissues anabolic changes predominate; the energy and heat required by the body result from the katabolic changes.

On account of the cardinal importance of the nitrogen content of protein, and the ease with which the metabolism of protein can be determined in terms of its nitrogen content, it is frequently convenient, in dietetic investigations, to refer to protein in terms of its nitrogen content. The nitrogen content of protein in many food-stuffs varies only slightly, so that if the amount of nitrogen is determined, the approximate amount of protein which it represents can be readily calculated by multiplying the nitrogen by an appropriate factor, usually 6·25.

In this connection it may be remarked that information regarding the dietetic habits of our people, the amount and character of the food materials habitually eaten by individuals at different ages and in different occupations is meagre and unsatisfactory. A considerable number of diets in selected classes of communities have been compiled and analysed both in the United States and in this country.* Although the actual numbers, especially in the United States, were large, it is still true that what is now needed is an extension of these studies so as to obtain a comprehensive survey of actually existing conditions which would throw more light upon the protein and energy intake of different classes of the population and furnish a rational basis for any action which may be necessary.

In recent years numerous investigations have shown that the body can preserve health and vigour on a diet containing less protein than the standards of Voit, Rubner and Atwater. In some cases amounts as low as 40 grams of protein a day appeared to be sufficient to meet protein requirements.

Although such small amounts of protein seemed to be adequate to preserve health and even vigour in the cases under investigation, many competent observers regard it as undesirable to reduce the protein supply to such low limits on the ground that the margin of safety is too small to enable the organism to cope satisfactorily with the various adverse circumstances in which it may find itself placed from time to time. It is considered that one of the remote consequences of a diet extremely low in protein might be a lowered resistance to disease and general diminution in physical tone; furthermore, that persons accustomed to a very low protein intake would be unable to assimilate an increased amount when necessary, as in convalescence from wasting disease.

Whilst, therefore, the adoption of diets excessively low in protein is not advocated, there appears to be little doubt that large numbers of people maintain good health and vigour on diets containing appreciably less protein than the amounts given in the standard diets of Voit, Rubner and Atwater.

In an investigation into the nitrogen consumption of seven laboratory workers, the average daily nitrogen excretion of each individual amounted to 13·5 gms. of nitrogen, equivalent to an intake of 93 gms. of protein.† A point of practical interest in this connection arises in regard to a sociological investigation by Rowntree,‡ at York, in which Atwater's standard of 125 gms. of protein was adopted as a minimum below which a

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* Many of the results are summarised in the Medical Research Committee's Special Report Series, No. 13, 1918, and details of the United States investigations can be found in the series of bulletins published by the U.S. Department of Agriculture.

† Hamill, J. M., and Schryver, S. B.: *Proc. Physiol. Soc.*, 24 March 1906.

‡ "Poverty: A Study of Town Life," B. S. Rowntree.

condition of poverty might be inferred. The lowest protein value encountered was 89 gms. a day, which is very little below the amount found adequate for the laboratory workers referred to above. Caution is, therefore, necessary in utilising protein consumption as an index of underfeeding.

It is an interesting fact that the protein content of foodstuffs in general is such that, in any ordinary mixed diet which supplies an adequate amount of energy for the average man, the protein content is somewhere in the neighbourhood of 100 gms. or more, so that in an ordinary mixed diet which suffices to meet daily energy needs, no anxiety need be felt as to the amount of protein provided. This conclusion has been expressed in the aphorism "Take care of the calories and the protein will take care of itself." With certain reservations in regard to the quality of the protein which will be considered immediately, this represents a good working rule.

There still remain for consideration certain very important facts in regard to protein which research has recently brought to light. In what has already been said, protein has been regarded as an entity; stress must now be laid on the fact that just as all flesh is not the same flesh, so all protein is not the same protein. Proteins differ very greatly in chemical composition according to the source from which they are derived, and this difference in their constitution affects their behaviour in metabolism and their utility from a nutritive point of view. From a chemical standpoint the protein molecule would appear to consist in essentials of amino-acids united together, or "conjugated" as it is commonly called. The various proteins differ from one another in regard to the nature and amount of the various amino-acid groupings which enter into their constitution. Thus, for instance, the two amino-acid groupings, tryptophane and lysin, which are found in a variety of proteins, are lacking in the protein, zein, which is the chief protein of maize. Variations in constitution such as that indicated exert a profound influence upon the suitability of individual proteins for purposes of nutrition. Experimental evidence shows that during digestion proteins are broken down into amino-acids, and that it is these acids which are utilised by the tissues to meet the various needs of the body's metabolism. It would, therefore, appear that no protein can be regarded as capable of satisfactorily meeting the requirements of nutrition unless it furnishes a sufficient quantity of the various amino-acid groupings necessary for the needs of the human body.

There are indications that tryptophane is an amino grouping of great importance in metabolism, and on that account it might be expected that zein, the protein of maize, from which the tryptophane grouping is absent, would be inadequate for meeting the body's requirements in regard to protein. Actual experiment has shown that this is the case. The mere nitrogen content of a diet is therefore not necessarily a sufficient criterion as to the

adequacy of the protein supply. A measure of the true value of proteins in nutrition appears to be their capacity to meet the organism's requirements in respect of the various amino-acids necessary for normal metabolism.

Attempts have been made to measure the nutritional values of proteins from different sources by determining their relative power in preventing loss of tissue protein from the body, and to these values the term "biological value of protein" has been applied.*

Up to the present these values have not been accurately determined, but the results already obtained would seem to demonstrate that proteins derived from animal sources are superior as conservers of body-protein to proteins derived from vegetable sources. The conception of the biological value of proteins has already led to important practical results. Evidence is accumulating which appears to indicate that one of the factors (if not the only factor) in the causation of the disease known as pellagra is a diet in which the protein is of low biological value. If this proves to be the case then pellagra may be regarded as a manifestation of disordered metabolism and nutrition consequent upon a diet defective in some essential particular, and may be included in the category of so-called "deficiency diseases." It is claimed that the symptoms can be abolished and the disease cured by the administration of milk, the protein of which has a high biological value. This is of significance in connection with the nutritive value of milk as an article of diet; the high biological value of the protein of milk makes it a food eminently suitable for the young where growth is rapid and the demands of the tissues for a supply of appropriate protein is urgent.

Carbohydrates and Fats.

The chief carbohydrates which the body obtains in food and utilises in metabolism are the starches and sugars (cane sugar, lactose, glucose and fructose). The starches during digestion are converted into sugar (glucose) and absorbed as such. Fats, whether derived from animal or vegetable sources, usually contain as their main constituents three types of fat, stearin, palmitin and olein, and the proportion in which these are present largely determines the consistency and melting point of the whole fat. When a considerable proportion of stearin is present, the fat is firm and hard, *e.g.*, mutton fat; when olein predominates, the fat is soft or liquid (oil), *e.g.*, olive oil. The carbohydrates and fats are the chief sources from which the body obtains the energy required for work and the production and maintenance of bodily heat. Within limits, carbohydrates and fats are interchangeable in isodynamic equivalents.† That is to

* Thomas, K.: *Archiv für Physiologie* (Rubner), 1909, p. 219.

† The isodynamic equivalents of carbohydrates and fats are the quantities of each which will furnish the same amount of energy. Approximately 2¼ parts by weight of carbohydrate supply the same energy

say, carbohydrates may replace fats and *vice versa* in the proportion of about 2¼ parts by weight of carbohydrate to 1 part by weight of fat. But it is not possible to replace the whole of the carbohydrate in a diet by fat, or to rely upon carbohydrate to the exclusion of fat without certain disadvantages in the general metabolism of the body.

In addition to the mere supply of energy, carbohydrates possess the property of enabling the body to satisfy its nitrogen requirements on a much smaller protein intake than would be the case in a diet in which carbohydrates are replaced by fat. To this property the term "protein-sparing" is frequently applied, and carbohydrates possess it to a greater degree than any other food material. It would appear that partial replacement of carbohydrate by fat in the diet may have little or no influence on the amount of protein metabolism, and it is stated that protein metabolism is not appreciably affected until the amount of fat is increased to such an extent that less than 10 per cent. of the total energy is supplied by carbohydrates.* When the proportion of fat in the diet reaches this point, fat metabolism does not proceed normally, acetone appears in the urine, and a condition of acidosis supervenes. When all carbohydrate is replaced by fat, still more acetone is produced and excreted, and the condition of acidosis becomes more marked.

Recent experimental inquiry seems to indicate that the human body performs work more economically on carbohydrate than upon fat, and when the work is sufficiently severe it is performed with greater difficulty upon fat and occasions greater fatigue.†

Although evidence points to the conclusion that metabolism becomes disturbed when too large a proportion of carbohydrate is replaced by fat, it would appear desirable that some fat should always find a place in the dietary, since there are indications that just as a certain proportion of carbohydrate is required to secure the proper utilisation of fat, so also some fat would seem to be required for the adequate utilisation of carbohydrate in the diet, but at present little is known as to the manner in which this effect is produced, or the amount of fat which it is desirable to include in the diet. Climatic conditions, manual labour and racial habits probably exercise considerable influence upon the proportion of fat which may customarily be taken in the diet; in some cases as small a quantity as 20 gms. per day seems to meet requirements; in other cases, where much work is done at low

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(calories) as one part by weight of fat, and consequently these are the isodynamic equivalents of the two proximate principles in question. The converse of the isodynamic equivalents is the amount of energy (calories) furnished by 1 grm. of carbohydrate and by 1 grm. of fat respectively as given in table on page 7.

* Zeller, H.: *Archiv für Physiologie* (Rubner), 1914, p. 213.

† Krogh, A., and Lindhard, J.: *Biochemical Journal*, 1920, xiv, p. 290.

temperatures, for instance, lumbering in Canada during winter, large quantities of fat are apparently utilised with ease. Present opinion is inclined to the view that it is desirable for the average individual in the British Isles to take at least 75 gms. (2·64 ozs.) of fat in the daily diet.

It is probable that there exists some ratio between fats and carbohydrates, possibly varying according to the circumstances and conditions in which an individual finds himself, which would best suit ideal nutrition, but knowledge is not yet sufficiently advanced to enable any definite pronouncement to be made on this point.

4. Mineral Requirements.

Very little is at present known in regard to the actual requirements of the body in regard to mineral substances. Since mineral substances are both absorbed and excreted by the intestine, it is impossible by a mere comparison of intake and output to ascertain how much has really been absorbed, quite apart from the more important question as to how much has undergone assimilation. Although practically no data are forthcoming as to the total mineral requirements of the body, indications have been obtained as to the amounts of certain elements such as phosphorus, calcium and iron, which may be needed. It has been possible, in the case of certain inorganic elements, to ascertain the equilibrium point at which their intake in the food is equal to their output in the excretions while the amount of the elements in question in the body remains constant. It does not, however, follow that such equilibrium indicates the minimum upon which the body can subsist, nor conversely does it follow that the attainment of equilibrium necessarily implies an adequate supply of the elements in question. Growth is most active during the first year of life, and after this period it is probable that the mineral requirements of the body become relatively less.

The phosphorus requirements of the body have been the subject of a large number of investigations, and have been variously stated as from about 1 to 2 gms. of phosphorus per day. The large variations which have been observed in the requirements of phosphorus would seem to depend, in part at any rate, upon the form in which the phosphorus is combined in the food; it would seem that phosphorus is more valuable for nutrition in certain combinations than in others.

As regards iron, the requirements of the body appear to be met by about 10 milligrams of this element daily, but it would seem desirable that more than this amount should be present in the daily diet.*

* U.S. Department of Agriculture (Office of Experiment Stations), Bulletin 185.

The requirements of the adult body for calcium have been variously given at 0·6 gm. of calcium (0·84 gm. of lime), 0·68 to 0·86 gm. of calcium (0·95 to 1·2 gms. of lime), 0·7 gm. of lime, 1·5 gms. of lime, and by Bunge at 3·3 gms. of lime daily. Albu and Neuberg consider that any diet supplying less than 1 to 1·5 gms. of lime daily is poor in calcium.*

The above quantities must be taken as indicating only the order of magnitude of the requirements of the body in respect of the elements mentioned; much more work requires to be done on the subject of the mineral needs of the body before definite pronouncement on this subject can be made.

It has been shown in animals that, even when the phosphorus in food is adequate, deficiency in calcium leads to abnormalities in skeletal growth (osteoporosis).† It would seem to be important, therefore, that during the period of skeletal growth, the CaO : P_2O_5 ratio should be high. In wheat, and all forms of flour derived from it, the above ratio is low.

There are indications that when there is a deficiency in the supply of organically combined phosphorus, the body is capable of making good the deficiency, to some extent at any rate, from inorganically combined phosphorus.‡ It is probable also that the same is true in regard to calcium.

It would appear that many diets, for instance, those in which wheat products and potatoes bulk largely, contain little calcium; the addition of oatmeal or peas and beans improves the calcium content, whilst milk very greatly increases the supply. An analysis of different diets shows that those in which milk forms an appreciable item are much richer in calcium than those in which this important article of diet is lacking. The value of milk in this respect, especially during the period of growth, is apparent; it corrects the calcium deficiency which is characteristic of many cereals which naturally must enter largely into most diets. A table showing the mineral content of some common food-stuffs is given in Appendix 3.

5. Accessory Food Factors, or Vitamins.

Research during recent years has shown that the human organism cannot maintain normal health and metabolism on a diet consisting merely of protein, fat, carbohydrate, inorganic salts and water, even though the amount of energy supplied is adequate and the protein sufficient in quantity and of suitable quality. It has been known for some years that pigeons, when fed on polished rice—that is to say, rice which has been deprived

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* Albu, A., and Neuberg, C.: *Mineralstoffwechsel* (Julius Springer), Berlin, 1906, p. 113.

† Ingle, H.: *Journal Agric. Science, 3*, p. 22.

‡ Hart, E. B., McCollum, E. V., and Fuller, J. G.: *American Journ. Physiol., 23*, p. 246. Holsti, O.: *Skandin. Archiv für Physiologie, 23*. p. 143.

of its germ and outer coatings or bran*—begin soon to suffer from disturbed metabolism and disordered nutrition, which ultimately manifest themselves in the diseased condition known as polyneuritis. The addition of rice bran to the diet of polished rice prevents the condition or cures it when it has supervened. It was also found that if mice were fed, not on natural foods, but upon mixtures of purified proteins, fats, and carbohydrates such as casein, egg-albumin, vitellin, potato-starch, wheat-starch and fat, together with the proper salts, their offspring were difficult to rear, and no living young could be obtained from the latter, even though all energy and protein requirements were adequately provided for. No satisfactory interpretation of these results was forthcoming until Professor Gowland Hopkins, of Cambridge University, suggested an explanation which accounted for the observed facts and opened up a new field of research which is being explored with growing success and gives promise of further discoveries of fundamental importance in the study of dietetics. Hopkins fed young rats on a diet of pure caseinogen, fat, carbohydrate and salts, and found that the rats soon ceased to grow and ultimately died. But by adding only a trace of fresh milk to the diet, normal growth and development were assured. The quantity of milk added was so small that its constituents were negligible as regards energy or material for tissue formation supplied by the milk. The total solids added to the diet by the milk did not exceed 0·08 gm. per day (later experiments have shown that the bulk of this is inactive), yet the daily increase in weight of the rats amounted to half a gram per rat. It was proved also that neither the protein, the salts, nor the lactose of the milk were responsible for the readjustment of the gravely disturbed metabolism and disordered nutrition, and, furthermore, watery extracts of other food-stuffs, such as mangolds, were found capable of producing a similar beneficial effect. The conclusion was unavoidable that, in certain food-stuffs, there was some substance or material, hitherto unidentified, which was capable of profoundly affecting metabolism, and without which the organism could not be properly nourished even though supplies of protein and energy in the diet were ample. It was obvious that this hitherto unrecognised substance in milk need be present in the diet only in remarkably minute amount, and must possess extraordinary potency. As a result of further investigation it became clear that there were other substances of similar nature which were responsible for proper nutrition and the maintenance of normal metabolism and development, and that, when these were absent from the diet, nutrition and metabolism became defective and ultimately manifested their defects in definite symptoms of disease. These substances are, therefore, essential for the

* For an account of the milling of rice, *see* Dr. J. M. Hamill's Report to the Local Government Board on "facing" and other methods of preparing rice for sale, Reports of Inspectors of Foods, No. 8, 1909.

maintenance of normal growth, health, and even life itself. For all substances of this category, Hopkins proposed the term "accessory food factors," and, later on, the alternative term "vitamins" came to be applied to them.

The nature of these substances is not yet understood, and little is known as to their chemical and physical properties or behaviour. Their presence or absence in any particular food-stuff can only be inferred from the effects produced on nutrition by the administration of the food-stuff in question; that is to say, they have not yet been isolated as definite entities whose individual characteristics can be determined.

No satisfactory means are at present available for estimating quantitatively the amount in which vitamins are present in food materials, or the amount of each particular vitamin which is necessary to maintain normal metabolism and development in any particular animal or at any definite age-period. In this connection the most that can be said is, that food-stuffs which in small quantities are able to prevent those disturbances in metabolism which characterise deficiency in a particular vitamin are richer in that vitamin than other food-stuffs of which larger amounts are necessary to prevent the occurrence of similar disturbances. Progress, however, is being made in the development of methods of quantitative estimation of accessory food factors.

Much of the work on vitamins has been done on small, rapidly-growing and prolific animals, such as rats, which form admirable test objects in regard to the adequacy of various experimental diets. But such animals are liable to display peculiarities of behaviour in regard to diets, and seem to be able to withstand certain deficiencies that are not tolerated by other animals. Thus the rat appears to be extremely resistant to deficiency of antiscorbutic vitamin, which in other animals results in the development of symptoms of scurvy. Considerations such as these have to be borne in mind, and due allowance made when applying results obtained from animal experiments to man. It is possible also that degrees of deficiency in diet which would unfavourably affect rapidly growing animals may be without effect upon animals which develop more slowly, or which have reached the adult stage. There are many points such as these on which further information is required, and can only be obtained as a result of much patient and laborious research; until such information is forthcoming, judgment must be suspended.

What is already known in regard to vitamins indicates their cardinal importance in nutrition, but it may here be remarked that in some quarters there appears to be a tendency to invoke unduly the vitamin hypothesis, and to make deductions and draw conclusions which information at present available is insufficient to justify. Present knowledge in regard to vitamins

necessitates caution in its application to far-reaching practical problems in dietetics if the error of building too vast a superstructure on an insufficient foundation is to be avoided.

6. Varieties of Accessory Food Factors, or Vitamins.

Research has so far disclosed the existence of three distinct accessory food factors, or vitamins, which are recognised by their special properties of preventing or curing certain disorders of metabolism and nutrition which ultimately manifest themselves as definite symptom complexes, and are then known as "deficiency diseases." Examples of such "deficiency diseases" are beriberi and scurvy, in both of which lack of a special vitamin in the diet appears to be the determining factor. In all cases of vitamin deficiency there is evidence which indicates that before nutritional disturbance has become so considerable as to produce the characteristic symptoms of a deficiency disease, minor and more subtle metabolic derangements which do not manifest themselves so plainly may occur and may tend to produce, amongst other disturbances, defective development and lowered resistance to infective disease. Further investigation, however, is necessary before definite and detailed pronouncements can be made on these points.

The three accessory food factors, or vitamins, at present known may conveniently be named according to the deficiency disease which each appears to be able to prevent or to cure, or at least to be a factor in its prevention or cure. Two of these vitamins have alternative names, which were originally applied to them by early investigators, and by which they are frequently described; there is evidence that these alternative names actually connote the same vitamin in each case, and they are accordingly given below in brackets.*

The three known vitamins are :—

(1) The anti-neuritic or anti-beriberi vitamin (also termed "water-soluble B" vitamin).

(2) The anti-rachitic vitamin (also termed "fat-soluble A" vitamin).

(3) The antiscorbutic vitamin.

7. Properties of the Vitamins.

1. The anti-neuritic (water-soluble B) vitamin prevents the occurrence of beriberi in man and analogous diseases (polyneuritis) in animals. It is also necessary to ensure satisfactory growth and development in young animals. The anti-neuritic vitamin withstands drying for long periods of time, and this is

* A full account of the known accessory food factors is given in the Medical Research Committee's Special Report Series, No. 38, 1919.

consonant with the fact that its principal sources are dry food-stuffs. It also displays considerable resistance to heat; it withstands prolonged exposure to a temperature of 100° C., but at higher temperatures, *e.g.*, 120° C., its destruction proceeds more rapidly. This vitamin can be extracted by alcohol, and also by water, from most of the food-stuffs in which it occurs; it is probable that its solubility is variable, depending upon the character of the food material in which it is deposited. The anti-neuritic vitamin is readily adsorbed from solutions upon the surface of various substances, such as charcoal, &c., but it has not been isolated as an entity.

2. The anti-rachitic (fat soluble A) vitamin is also necessary for normal growth and development to occur in young animals. In young rats, not only does growth cease when the anti-rachitic factor is lacking in the diet, but the animals become very susceptible to bacterial infection. This lowering of resistance to infective disease manifests itself in many cases by the appearance of an infection of the eye which seems to be of the nature of a xerophthalmia. So characteristic is this manifestation that some observers regard it as almost a specific result of a deficiency of the anti-rachitic vitamin.

Rickets, the chief manifestations of which are abnormal and defective bone formation, probably results from the interplay of more than one causal factor. Such information as is at present available points to defective nutrition (possibly prenatal as well as postnatal) as having an important bearing upon the production of rickets. Certain experimental evidence would seem to indicate that deficiency of fat-soluble A vitamin in the diet is one of the causes of the defective nutrition which ultimately manifests itself as rickets, but opinion is not unanimous on this point.

The anti-rachitic vitamin (now considered as probably identical with fat-soluble A vitamin) cannot be extracted from animal tissues by water, but is soluble in fat and in substances which dissolve fats. This vitamin occurs in green leaves, but in this situation it cannot be extracted by ordinary fat solvents. Fat-soluble A vitamin shows considerable resistance to the destructive action of heat when heated out of contact with oxygen, but, in the presence of oxygen, exposure to moderate temperatures, *e.g.*, 100° C., for relatively short periods (1 to 2 hours) will result in its destruction. The process of destruction appears, therefore, to be mainly one of oxidation.

3. The antiscorbutic vitamin possesses the power of preventing or curing disturbances in metabolism which result in the disease known as scurvy when this vitamin is lacking in the diet.

The antiscorbutic vitamin is soluble in water and in alcohol, and can be dialysed and filtered through a porcelain filter without appreciable loss. Unlike the anti-neuritic vitamin, it is not adsorbed upon the surface of fine precipitates such as colloidal iron, &c., and this difference provides a method whereby anti-neuritic and antiscorbutic vitamins can be separated in a solution

containing them. The antiscorbutic vitamin is sensitive to heat, and is readily destroyed by boiling. At a temperature ranging from 80° to 100° C. about 90 per cent. of the vitamin is destroyed in one hour. The vitamin appears to be especially sensitive to heat in alkaline media which, even at ordinary temperatures, exert a rapidly destructive influence upon the vitamin. Possibly oxidation may play a part in its destruction.

8. Distribution of the Vitamins in Nature.

It would appear that the animal organism is incapable of producing vitamins for itself, and consequently all animals are dependent for their supply directly or indirectly upon the vegetable kingdom. It follows, therefore, that any vitamins present in meat, fat, or other food of animal origin, must have been ultimately derived from vegetable sources. It is evident that this generalisation is of the utmost importance in connection with practical dietetic problems.

The sources of the three known vitamins may now be considered in detail.

1. The anti-neuritic (or water-soluble B) vitamin occurs in the seeds of plants; the chief of these for food purposes are the cereals and edible pulses which consequently form one of the main sources of supply of the anti-neuritic vitamin.

In cereals the vitamin is not distributed uniformly throughout the grain; the bulk of it is limited to the embryo, or germ, a small proportion being found in the bran (the pericarp and aleurone layer). In wheat and rice the germ appears to contain from five to ten times more of the vitamin than the bran. The endosperm is deficient in anti-neuritic vitamin.

In pulses the anti-neuritic vitamin appears to be uniformly distributed throughout the seed, since in these seeds the embryo occupies the whole bulk of the seed, its reserve food supply being contained within the embryo itself and not separately stored in endosperm as is the case in cereal grains. Eggs are rich in the anti-neuritic vitamin which has been found to remain unimpaired in dried eggs; this indicates that the ordinary process adopted for drying eggs does not destroy the vitamin.

Yeast is also rich in anti-neuritic vitamin; commercial preparations made from yeast are largely used as a substitute for meat extract in the preparation of soup cubes, &c., and retain the vitaminic activity of the yeast unimpaired.

Meat is relatively deficient in the anti-neuritic vitamin, but it seems that the offal, *i.e.*, internal organs, such as heart and liver, contain it in rather larger amounts than the "flesh" or skeletal muscle. Fish, milk and cheese also seem to be relatively poor in this vitamin.

2. The anti-rachitic (or fat-soluble A vitamin) is found in certain fats of animal origin, such, for instance, as beef fat, cod-

liver oil, the fat of kidneys, heart muscle and liver tissues, also butter, milk and cream. The primary source of the vitamin is, however, the green leaves of plants, and it is from the consumption of these that plant-eating animals obtain the vitamin and store it in the fatty tissues of their bodies. The vitamin in cod-liver oil must similarly be presumed to have been ultimately derived from the tissues of algae, or sea-water green plants.

Root vegetables in general are deficient in fat-soluble A vitamin (though certain of them, such as carrots, seem to contain appreciable amounts of this vitamin), and so also are most oils and fats derived from plant sources, such as olive oil, cotton-seed oil, &c.

It is obvious that the fat of plant-eating animals may show great variation in its content of fat-soluble A vitamin according to whether the animals' diet included green plants or not. Thus in the winter time, if green food is lacking, the milk of cows and butter made from it are deficient in fat-soluble A vitamin, similarly lard obtained from pigs fed on a diet from which green food is absent will lack fat-soluble A vitamin.

The processes used in extracting and preparing fats may impair or destroy any vitamin which they already contain; the vitamin content of lard may be impaired in this way, even though the pig had been fed in such a manner that its fat contained the vitamin. Oils are nowadays converted into solid fats by the process of hydrogenation, and in this process the vitamin which they may contain is destroyed. Such hardened fats may be employed in the manufacture of margarine.

3. The antiscorbutic vitamin is found in the green leaves of plants, especially members of the natural order Cruciferae, *e.g.*, cabbage. When it is difficult to obtain a supply of green vegetables, seeds, such as mustard and cress, which in themselves are devoid of antiscorbutic properties, may be germinated; the seedlings are rich in antiscorbutic vitamin. Roots vary greatly in antiscorbutic power, swedes being superior to carrots and beetroots. Potatoes (tubers) and onions contain the antiscorbutic vitamin in appreciable amount. The vitamin is also present in fresh fruits; oranges and lemons contain it in considerable quantity, and are superior to the lime fruit in antiscorbutic properties. Preserved lime juice, dried fruit and dried vegetables, are practically destitute of any antiscorbutic power. Both meat and milk have a low antiscorbutic value.

9. The Bearing of the foregoing Considerations upon the Adequacy of Diets.

It is clear from what has already been said that the selection of an appropriate diet, which will produce the optimum results in nutrition, involves many considerations. All the various requirements of a satisfactory diet may be provided except in respect of one essential particular, for instance, fat-soluble A vitamin, and

the absence of this is sufficient to render an otherwise excellent diet unsuitable for normal development. It is quite possible to arrange a diet which is pleasing, satisfying, and even luxurious, but which is, nevertheless, unsatisfactory from a nutritive point of view, and will not produce the best results in regard to development and the maintenance of normal health. Conversely, it is not impossible to frame a dietary which is simple and which will meet all nutritional requirements in a satisfactory way.*

In considering the question of dietaries it is obvious that the most exacting demands in regard to the adequacy of dietary constituents will be made during the period of life in which growth is most active, and it is essential that these demands should be met properly in order to ensure satisfactory development, resistance to disease and the maintenance of health and efficiency in adult life. The dietaries of different races of mankind vary considerably in regard to individual constituents, in some, for instance, one type of cereal such as rice predominates, in others meat is rarely eaten, and in others dairy products are lacking. It is possible, however, to group the chief food-stuffs used by mankind into the following simple categories :—

(1) Seeds, *e.g.*, cereals and pulses.
(2) Tubers, *e.g.*, potatoes.
(3) Roots, *e.g.*, carrots, parsnips, turnips, &c.
(4) Meat.
(5) Leaves, *e.g.*, cabbages and other green vegetables.
(6) Fruits, *e.g.*, oranges.
(7) Milk and milk products.

Animal experiments have shown that a diet consisting exclusively of seeds is inadequate to promote growth or maintain life. Wheat, which may be taken as a typical seed, proves to be too poor in fat-soluble A vitamin and in such mineral constituents as calcium, sodium and chlorine, even when the whole of the wheat grain is utilised. Its protein also possesses too low a biological value for satisfactory nutrition. The biological value of the protein in a seed diet is enhanced when the diet instead of containing only one seed contains several different varieties, but even then it falls below what is desirable.

Tubers and roots suffer from defects of a similar kind to those of seeds. They are in most cases deficient in fat-soluble A vitamin, and are poor in calcium, sodium and chlorine. Potatoes which have been peeled are also deficient in water-soluble B vitamin.

Green leaves contain satisfactory amounts of the constituents which are deficient in the preceding groups of food-stuffs, namely, fat-soluble A vitamin, protein of a character suitable for supplementing the defects in the protein of seeds, and also a sufficiency

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* A lucid exposition of the broader aspects of nutrition will be found in "The Newer Knowledge of Nutrition," by E. V. McCollum. (The Macmillan Company, New York, 1919.)

of mineral matter. The addition, therefore, of green leaves in adequate quantity to a diet of seeds, roots and tubers, would appear to compensate for the defects of such a diet, and to render it satisfactory. Unfortunately, however, for omnivorous animals, of which man is one, the bulk of green vegetables which would probably be necessary to ensure an ample margin of safety would, in most cases, impose undue strain upon the digestive organs.

Meat may be divided into two classes—(1) that derived from skeletal muscle, (2) that derived from internal organs, such as liver, kidney, pancreas, &c. The general term "offal" is commonly applied to meat of this second class. Skeletal muscle is superior to seeds mainly in respect of the higher biological value of its protein. Its content of fat-soluble A vitamin is not high, and in this respect it does not appreciably reinforce a seed diet. If much fat is present, of course, the value of meat as a source of fat-soluble A vitamin is enhanced. Skeletal muscle, or meat as it is commonly called is, therefore, a useful supplementary food to a diet consisting of seeds or seed products, tubers and roots, especially on account of its higher biological protein value. The glandular organs—"offal"—appear to be more valuable as a source of essential constituents of the dietary than skeletal muscle, in so far as they contain a greater amount of both fat-soluble A and water-soluble B vitamins.

Fish may be divided into two classes—white fishes and oily fishes. It is probable that the former, in so far as essential dietary constituents are concerned, closely approximates to skeletal muscle in quality. The oily fishes, such as herrings, &c., are more valuable as a constituent of the dietary, not only on account of their higher energy value, but also owing to the fat-soluble A vitamin which their oil contains.

Eggs are a very useful addition to a diet, the yolk especially being rich in fat-soluble A and water-soluble B vitamins.

Milk is a food material of special importance. Many of the most widely used foods which are valuable sources of energy are, at the same time, either singly or in combination in a dietary, deficient in certain constituents essential for normal growth, development, and maintenance of health. Milk contains all these constituents, and when used in conjunction with such food-stuffs, be they either of animal or vegetable origin, it corrects their dietary deficiencies. The biological value of milk protein is high, and on this account milk proteins are superior to those of any foods derived from vegetable sources. Milk is also rich in both fat-soluble A vitamin and contains a certain amount of water-soluble B vitamin; in addition, it is rich in mineral substances, especially calcium. It has already been seen that green leaves have the power of compensating for certain dietary deficiencies, notably fat-soluble A vitamin, and in this respect are useful in supplementing the supply of this vitamin in milk. Furthermore, green leaves possess in a high degree, together

with certain fruits (especially citrus varieties), the antiscorbutic vitamin, which is deficient in most other classes of food-stuffs.

If, therefore, a diet which is adequate, so far as its energy supply is concerned, is to be made safe in regard to the supply of other constituents essential for proper nutrition, this can best and most simply be assured by the addition of milk and green leaves to the diet. The value of milk and green leaves in ensuring the safety of a diet has earned for them the term "protective foods."

It is quite possible that a mixed diet consisting of the commonly utilised classes of foods (seeds, tubers, roots and meat) might be so constituted as just to supply enough of each constituent necessary for nutrition. Some of the mineral salts, calcium, sodium and chlorine, would probably be low in amount, but in emergency it appears to be possible for the body to utilise inorganic sources to supply deficiencies. Hard water might suffice to make up the necessary calcium, and common salt the other two mineral elements. In nearly all ordinary diets composed of food-stuffs of the above classes, the supply of water-soluble B is usually sufficient; its relatively wide distribution throughout food-stuffs would ordinarily ensure requirements being met by all usual mixed diets. It would seem, however, to be otherwise in regard to fat-soluble A vitamin, which is not so widely distributed throughout the various food materials of which diets are commonly composed. Although it may be possible to obtain a sufficient supply of fat-soluble A vitamin on a "seed, tuber, root, and meat" diet in which the representatives of each class are carefully selected and varied, it is possible that the amount may in some cases be perilously near the border line of safety, and may place the consumer in what has been called "the twilight zone," within which a very slight change in any of the dietary components may cause an important shift of balance in the wrong direction. There is experimental evidence to show that a diet which contains just enough fat-soluble A vitamin becomes inadequate in regard to fat-soluble A vitamin when the protein content is lowered. Conversely, when there is an ample supply of protein of high biological value, and also of mineral matter, an amount of fat-soluble A which would otherwise be inadequate may then suffice. That is to say, adequacy in respect of one essential constituent may be converted into inadequacy when the balance in respect of some other constituent of the diet is altered. Observations of this kind make it evident that it is impossible to say what is the safe minimum of any dietary factor unless the biological values of all the other essential constituents of the diet are known. When the constituents of a diet are such as to bring the consumer into the so-called "twilight zone," any small shifts in the quality of the diet with respect to any factor may either stabilise the processes of metabolism or may lead to abnormal and pathological results.

A diet consisting of seeds or seed products, tubers, roots and meat must after all constitute the bulk of the diet of man, and if such a diet should happen to be within the "twilight zone," it would appear that it can be raised into the region of safety by the addition of the protective foods—milk and leafy vegetables.

10. The Preparation of Food in Relation to Nutritive Value.

The effect of the various processes which food may undergo in its preparation for consumption upon the vitamin content of the food and its nutritive qualities demands consideration. It will suffice perhaps to deal with a few of the more representative and important food-stuffs; other instances will naturally group themselves about these typical examples or will readily admit of judgment on similar considerations.

Bread.—In the milling of white flour the object sought is to eliminate as much as possible of the outer coats of the grain (bran) and the embryo or germ, so that the resulting flour shall consist, as far as is practicable, of the contents of the cells of the endosperm. Since only very small amounts of the bran and germ remain in the finished flour, the latter is proportionately deficient in water-soluble B vitamin when compared with the original wheat grain or other varieties of flour containing various proportions of germ and branny particles. But when flour is made into bread, yeast is used in the process in quantities usually amounting to rather less than one per cent. of the flour employed, and yeast is extremely rich in water-soluble B vitamin. Now, as the germ represents roughly 1·5 per cent. of the wheat grain, and contains about four-fifths of the total content of water-soluble B vitamin present in the grain, the amount of water-soluble B vitamin contributed by the yeast would seem to be, at any rate, of the same order of magnitude as that contributed by the germ and outer coats of the grain. The commonly presumed disadvantages of bread made from white flour as compared with bread made from less highly milled flour, in respect of the relative water-soluble B vitamin content of each, would seem therefore to be less serious than might at first be supposed. Experimental evidence suggests that requirements in regard to water-soluble B vitamin are easily satisfied, and there is nothing yet to show that these needs would not be met by the yeast in white bread even though such bread bulked largely in the diet.* An objection of a higher order and of greater weight could be urged against the undue prominence in a diet of bread

* It is, of course, desirable that the processes to which food is subjected should not, if possible, diminish its content of any constituent which is inherently valuable in nutrition. At the cessation of Government control (31st March 1921) an average extraction of 76 per cent. "straight run" flour was being produced. This flour makes excellent bread, and

made from any variety of flour, since most of the ordinary cereals used for food are deficient in fat-soluble A vitamin and contain protein of low biological value. The truth appears to lie in the fact that bread, so far as it supplies the needs of the body in respect of energy, protein, and mineral matter, is a good food, but that none of the cereals alone is a complete or ideal food. A mixture of different seeds is superior to one variety of seeds only, since the proteins of different seeds differ somewhat amongst themselves, and one may supply an important amino-grouping which may be lacking in another. Satisfactory nutrition is to be obtained only through variety and the right combination of foods. The various food-stuffs upon which mankind has to exist must be accepted and, instead of condemning them because this one or that is lacking in some respect, they should be utilised in combination to the best advantage.

Margarine.—The chief constituents of margarine are vegetable oils such as cotton-seed oil, arachis oil, &c., and animal fats such as "oleo" and lard. Lately these have been supplemented by hydrogenated or "hardened" fats, and fats of this kind have to some extent replaced "oleo," which is relatively expensive and sometimes difficult to obtain. These fats and oils are mixed by churning with a proportion of skim milk. It is evident that the fat-soluble A vitamin content of margarine depends almost entirely upon the proportion of animal fat, other than lard, which it contains, and where this fat is replaced by hardened fats, the vitamin content of the margarine so produced may be very low. In respect of vitamin content such margarine contrasts markedly with butter, for which it is used as a substitute. It is unfortunate that economic conditions should necessitate the curtailment of the use of animal fats in margarine, but in so far as margarine is a fat and a valuable source of energy, it is an important food-stuff, and its use should not be condemned merely because of its possible poverty in vitamins. If necessary the fat-soluble A vitamin should be supplied from other sources.

During late years margarine has largely replaced butter in the diets of considerable sections of the population, mainly on

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may be regarded as being slightly richer in water-soluble B vitamin than a "patent grade" flour, which is a more highly refined fraction of the wheat. Whether the difference is of any practical moment it is impossible to say definitely in the present state of knowledge. It is possible that a demand for highly refined flour may reassert itself, and to meet it the milling of "patent grade" flour may be resumed. The fact is that bread eaters in general prefer white bread to bread made from less highly milled flour, and it would be impracticable to coerce a community into consuming bread which might have advantages from a health point of view, but which is not relished. In such matters æsthetic considerations have much greater weight than those pertaining to well-being.

For other aspects of this subject, *see* Dr. J. M. Hamill's Report to the Local Government Board on "The Nutritive Value of Bread made from Different Varieties of Wheat Flour," 1911. [Cd. 5831.]

account of the shortage and high price of butter.* It is not clear, however, whether the use on the present scale of margarine deficient in animal fat reduces the total fat-soluble A vitamin content of the diet to such an extent as seriously to impair the vitamin value of the diet; further inquiry is necessary to determine, if possible, this point.

Lard is an example of an animal fat which is usually deficient in fat-soluble A vitamin. This deficiency is not a necessary condition or peculiar to the pig, but appears to depend upon two factors. The first of these is the very general practice of feeding pigs on a diet poor in fat-soluble A vitamin, in consequence of which the animals are unable to store a sufficiency of the vitamin in their fatty tissue. The other factor consists in the process by which lard is extracted on the commercial scale, where it may be subjected to temperatures sufficiently high and prolonged in the presence of air to destroy any fat-soluble A vitamin which the fat may initially have contained.

Cooking of Green Vegetables.—The rate of destruction of antiscorbutic vitamin is a function both of the temperature to which it is exposed and the duration of exposure. Within the range of temperature ordinarily employed in cooking, *e.g.*, 100° C. for boiling and 80° C. for simmering, the duration of exposure to these temperatures appears to be more important in the destruction of the vitamin than the differences in temperatures themselves. Cooking green vegetables for a short period of time at the higher temperature is therefore to be preferred to cooking them for the much longer time necessary at the lower temperature. For this reason, the method of slow cooking at temperatures somewhat below 100° C., as in the case of the so-called "hay box" method of cooking, is not suitable for green vegetables, and for the same reason green vegetables should not be cooked in stews, where the vitamin is exposed to a destructive temperature for relatively long periods. The antiscorbutic vitamin is also extremely sensitive to alkalies, and on this account the practice of adding soda to the water in which green vegetables are boiled is undesirable. When vegetables are steamed they retain more of their mineral constituents than when boiled.

The process of drying vegetables is destructive of antiscorbutic vitamin, and consequently dried vegetables are useless as antiscorbutics.

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* The monthly average consumption, in tons, of imported and home produced butter and margarine, from 1915 to the end of the first half of 1919, was as follows :—

—	1915.	1916.	1917.	1918.	1919. 6 months.
Butter - -	26,271	18,277	15,455	11,716	13,332
Margarine -	18,166	22,212	22,768	21,205	28,686

Milk.—It has already been mentioned that experimental evidence seems to indicate that milk is a most important "protective food." In any ordinary mixed diet, consisting as it must do mainly of seeds, tubers, roots, and meat, there is the possibility of one or more essential substances being lacking, or present in amount insufficient for satisfactory nutrition; the addition of milk to such a dietary would appear to raise it above the zone of possible danger and ensure its safety for all purposes of nutrition. It is, however, important to realise that milk may exhibit serious variations in its protective power, depending upon the conditions under which it is produced. The cow, as a member of the group of herbivora, possesses the ability of transmuting vegetable protein in its food into milk protein, which has a much higher biological value. It seems, however, to have no power to produce *de novo* fat soluble A vitamin, so that whatever fat-soluble A vitamin the milk may contain must have been derived directly from the vitamin present in the green vegetable food which the cow has consumed. The greater, therefore, the supply of green food (grass), the richer will the milk be in fat-soluble A vitamin, and if green food be lacking from the dietary of the cow, as is frequently the case in stall-fed cows in winter, the milk produced will be deficient in fat-soluble A, and to this extent its value as a protective food will be impaired. It is, therefore, important that milch cows should receive as large a proportion of green vegetable food as possible; the ideal conditions for the production of milk of satisfactory quality are attained when the cows are being grazed.

Human milk likewise varies in its nutritive quality in accordance with the supply of fat-soluble A vitamin in the mother's diet. Although human milk is normally superior to cow's milk for infant nutrition, there is evidence that these values may be reversed where the mother's diet is deficient in fat-soluble A vitamin, and the cow is being fed on a diet in which grass bulks largely. It is therefore essential that the diet of a nursing mother should be rich in fat-soluble A vitamin, and in no way can this more readily be ensured than by including in her dietary cow's milk containing a satisfactory supply of the vitamin. Eggs and green vegetables are valuable as a supplementary source of supply.

Milk also possesses a definite but low antiscorbutic value. A point of practical importance is whether infantile scurvy is likely to supervene as a result of feeding with pasteurised, sterilised, or dried milks. There has been considerable divergence of opinion in regard to dried milk, but recent research seems to show that in the ordinary processes of drying milk its antiscorbutic properties are not seriously impaired.

Having regard to the fact that the antiscorbutic properties of milk are low, and the possibility that dried milk if kept for any length of time before consumption may suffer still further loss

of antiscorbutic properties, the policy of "safety first" has much to recommend it, and in conformity with this the administration of small quantities of orange juice to infants fed on dried milk, or indeed on any milk, is a desirable precaution.

11. Conclusions.

In the foregoing discussion it has not been possible to do more than indicate the complicated variety of factors which may influence the nutritive value of a diet, but out of the maze of considerations which are involved, certain generalisations appear to emerge which, if used with caution and a recognition of the fact that present knowledge does not permit of final judgment, may serve as useful guides in the solution of practical dietetic problems.

The ordinary materials which are readily available for the food of mankind—seeds, tubers, roots and meat—are competent to supply the energy required for the maintenance of life; such food-stuffs must of necessity constitute the bulk of any dietary, but it is quite possible that a dietary of this kind, though ample in amount, may be seriously deficient in constituents essential for normal nutrition, growth and development. Limitation of the diet to too few articles from the above groups, and the mode of preparation and the subsequent cooking of food-stuffs, may aggravate the deficiency; on the other hand, the careful selection of food-stuffs and the use of a variety of foods from the above categories may ensure the presence of a sufficiency of essential substances. In the present state of knowledge it is not possible to say with any exactness where a diet begins to be unsatisfactory in respect of its content of essential substances. There is, as it were, a region of doubt, the "twilight zone" as it has been called, in which small variations in the diet may make all the difference between adequacy for nutrition and the reverse. It is possible that large sections of a community may be living within this zone, that the deficiencies in a diet may be intermittent and variable in nature, or so small as not to produce disturbance of metabolism sufficiently marked to be recognisable as definite disease; nevertheless such deficiencies may result in minor and more subtle derangements of nutrition which may manifest themselves in defective physical development and lowered vitality. More precise and extensive information on this subject is needed and may be hoped for from future research. The point of practical importance which has emerged is that milk and green vegetables afford a means of raising any ordinary diet into the plane of safety, and pending further knowledge little fear may be entertained as to the satisfactory nature of any mixed diet into which milk and green vegetables enter, provided, of course, that the diet is sufficient in amount to afford the necessary supply of energy. It is not possible to say how much milk a diet should contain: this will depend largely upon the richness

of the other articles of the diet in the essential constituents which milk provides. In the absence of definite knowledge on these points it would appear desirable that during the period of growth, at any rate, the amount of milk in the daily diet should be somewhere in the region of a pint;* it might with advantage be even more. At the present time the average daily milk consumption of the population of England and Wales has been estimated at about $\frac{1}{4}$ pint per head, and in some populous districts is as low as 0·08 or even 0·06 of a pint per head.† A pure and abundant milk supply, readily procurable by all classes, is one of the essential factors in any sound scheme of nutrition.

The period of growth is the most important period of life, since upon satisfactory growth and development during this time the efficiency and well-being of adult life depend. In adult life, when development has been completed, it is probable that the need for some of the essential constituents is relatively less than during the period of growth, so that a diet which is safe during the period of growth in regard to essential constituents, is almost certain to be adequate for adult life, always, of course, assuming that a sufficient energy supply has been assured.

It will readily be inferred from the foregoing, that where a diet is supplemented by milk and green vegetables, the food materials of which the diet is composed may quite satisfactorily consist of articles which are easily obtained and relatively cheap. Examples of such food-stuffs are—flour and its products, bread, &c.; oatmeal; the pulses, *e.g.*, peas, beans, and lentils; potatoes and roots, such as parsnips, carrots, &c.; sugar and fats of all kinds. In regard to meat, it has already been mentioned that offal, which has the advantage of cheapness, appears to be dietetically superior to skeletal muscle (ordinary "meat").

Caution should be exercised in comparing the monetary value of one food-stuff with another if misleading conclusions are to be avoided. It is possible to compare fairly satisfactorily the monetary and dietetic value of the various cereals amongst themselves, and also to compare tubers, such as potatoes, with various roots, when the point at issue is the energy value of these materials uncomplicated by other considerations. But to compare the monetary values of these classes of food-stuffs with other foods, such as milk, eggs, and leafy vegetables, may lead to fallacious results, since the dietetic considerations involved are not merely quantitatively but qualitatively dissimilar and do not admit of simple comparison.

A final point for consideration is the effect of cooking upon the palatability and digestibility of food. Food which is so cooked as to be pleasing to the palate stimulates the secretion of

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* Second Interim Report of the Committee on the Production and Distribution of Milk [Cmd. 8886], p. 6, issued in November, 1917.

† Final Report of the Committee on the Production and Distribution of Milk [Cmd. 483]. 1919.

digestive juices in a way which unpalatably cooked food is incapable of doing. The actual digestibility of food can also be impaired by bad cooking. In order, therefore, that the most should be made of any diet, care and attention should be devoted to its preparation and cooking. It is to be feared that in many instances excellent food materials do not receive the treatment which they merit at the hands of those entrusted with their cooking. In this failure incompetence and apathy play their part, but ignorance and lack of facilities are accountable for much and are more easily remedied. For those who are desirous there are numerous opportunities of acquiring a knowledge of simple cooking, and an extensive literature exists on the subject.

It is probable that much of what has been said in this report may need modification in the light of future discoveries. Knowledge of the principles underlying nutrition has been greatly extended as a result of recent research, but it is evident that much yet remains to be done. Progress in this work of national importance can be attained only by unremitting observational and experimental inquiry. The problems awaiting investigation are amongst the most difficult which can be proposed for solution, and their elucidation will entail much labour and patient research. It was in this country, in the University of Cambridge, that the work which led to the two great dietetic conceptions—vitamins and the biological value of protein—largely had its origin, and it is only fitting that this country should continue to maintain its position in the world-wide search which is being vigorously prosecuted into the principles upon which sound nutrition and a rational system of dietetics can alone be based.

SUMMARY.

1. Food is necessary for (1) supplying material for the growth of the body and the repair of waste and (2) furnishing the energy required for muscular work and the maintenance of bodily heat.

2. The essential constituents of food can be grouped under the following classes of substances:—(*a*) proteins, (*b*) carbohydrates, (*c*) fats, (*d*) mineral matter, and (*e*) vitamins, or accessory food factors. A diet which is defective in respect of any of these groups cannot be regarded as satisfactory for nutrition.

3. The energy required by the body for work and heat may conveniently be measured in terms of Calories. The energy requirements of the body vary according to a variety of circumstances, such as size, weight, age, sex, occupation, and environment. The energy requirements of an average man engaged in

moderate work are, approximately, 3,300 Calories per day; a woman in similar circumstances requires about four-fifths of this amount and children from a half to four-fifths according to age.

The energy which various food-stuffs can supply has been determined and tabulated in terms of Calories, and from such tables the amount of the various food materials needed to furnish the energy requirements of the body can be ascertained.

4. The chief sources of energy in food-stuffs are the carbohydrates and fats. Within certain limits, carbohydrates and fats are interchangeable as sources of energy, but there is evidence which indicates that neither should be entirely absent from a diet.

5. The protein in a diet contributes its share of energy, but its chief function is to supply material for the repair of waste or wear and tear of the tissues of the body, and for growth. All ordinary mixed diets which supply an adequate amount of energy for the daily needs of the average man contain sufficient protein to meet requirements.

Proteins vary in their composition according to the source from which they are derived, and the value of any given protein in nutrition depends upon its composition. A measure of the true value of proteins in nutrition appears to be their capacity to meet the organism's requirements in respect of the various amino-acids necessary for normal metabolism. To this capacity the term " biological value of protein " has been applied. The biological value of the proteins of milk and of meat is superior to that of proteins derived from vegetable sources such as cereals.

6. In regard to mineral requirements, certain important groups of food-stuffs, such as most of the cereals and tubers, are low in calcium, whereas milk is rich in this important element. Milk, therefore, is able to correct the calcium deficiency of these groups of food-stuffs which must of necessity enter largely into most diets.

7. Vitamins are essential for normal growth and health Their nature is not understood, and they have not yet been isolated. Their presence or absence in any particular food-stuff can only be inferred from the effects on nutrition produced by the administration of the food-stuff in question. Animals are dependent for their supply of vitamins upon the vegetable kingdom; they are incapable of producing vitamins *de novo.* Three different vitamins, fat-soluble A, water-soluble B, and the antiscorbutic vitamin, have so far been distinguished. Both water-soluble B and fat-soluble A vitamins seem to be essential for normal growth and development. Deficiency in water-soluble B gives rise to beriberi in man and analogous conditions (polyneuritis) in animals, and there is evidence that a deficiency in fat-soluble A may be a factor in the causation of rickets. The antiscorbutic vitamin prevents the development of scurvy, and cures the condition when it occurs. Water-soluble B vitamin

is found notably in the seeds of plants, consequently the cereals and pulses are an important source of supply of this vitamin. The vitamin occurs chiefly in the embryo, and to a lesser extent in the outer coat or bran; in pulses it is distributed throughout the seed. Eggs and yeast are also rich in water-soluble B vitamin; meat, fish, milk, and cheese contain relatively small amounts. The primary source of fat-soluble A vitamin is green leaves. Animals, when fed on green leaves, store up the vitamin in their fatty tissues, so that animal fats, milk and butter, obtained from animals fed on green food are rich in this vitamin. Most vegetable oils or fats, and, in general, roots and tubers, are deficient in fat-soluble A vitamin. The antiscorbutic vitamin is found in fresh green leaves and fresh fruits, especially oranges and lemons. Roots and tubers contain it in appreciable amounts.

The antiscorbutic vitamin is readily destroyed by drying; exposure to temperatures of 80° C. to 100° C. for one hour destroys 90 per cent. of the antiscorbutic vitamin content of vegetables, and the destruction is still more rapid if the vegetables are boiled with an alkali such as soda. Water-soluble B vitamin withstands drying, but is gradually destroyed at 120° C. Fat-soluble A vitamin is destroyed by heating to a temperature of 100° C. for one to two hours in the presence of oxygen (air).

8. The chief food-stuffs of mankind can be grouped according to their nature into the following categories :—(1) seeds, (2) tubers, (3) roots, (4) meat, (5) leaves, (6) fruits, (7) milk and milk products. A diet consisting of seeds, tubers, roots, and meat may be deficient in fat-soluble A vitamin and calcium; the inclusion of leaves (green vegetables) and milk in the dietary corrects these deficiencies.

9. The processes which food undergoes in preparation may impair its vitamin content; thus flour may be deprived of much of its water-soluble B vitamin in milling; lard may lose in the process of manufacture any fat-soluble A vitamin which it may possess, and margarine made from vegetable oils, lard, and "hardened" fats, may also be deficient in fat-soluble A vitamin. Green vegetables may have their antiscorbutic properties destroyed by prolonged boiling, or by the addition of soda to the water in which they are boiled. In the making of bread, the addition of yeast is probably sufficient to correct the loss of water-soluble B vitamin incurred in milling.

10. There would seem to be greater risk of a diet being deficient in fat-soluble A than in water-soluble B vitamin, since fat-soluble A vitamin is not so widely distributed amongst food materials as is water-soluble B vitamin. By suitable selection and variety it may be feasible to construct a diet consisting of seeds, roots, tubers and meat, *i.e.*, the staple material of most diets, which may contain all that is necessary for normal nutrition, but the possibility cannot be ignored that a diet constructed from these important food-stuffs, whilst adequate as regards energy production, may be deficient in certain respects,

notably in fat-soluble A vitamin. The addition of milk and leaves (green vegetables) to such a diet would appear to be sufficient to raise it into the plane of safety, and for this reason milk and green vegetables have been termed "protective foods." In adult life the need for certain essential constituents (vitamins) is probably less than during the period of growth, so that a diet which is satisfactory during this period is almost certain to be adequate for adult life, assuming that a sufficient energy supply is assured.

11. In order that a dietary should include all the essentials for nutrition, it should be as varied as possible. All available evidence indicates the undesirableness of limiting a diet to a few varieties of food material. When a diet is supplemented with milk and green vegetables, the most readily obtainable foods from the classes of seeds, roots, tubers and meat, such as flour, bread, &c., oatmeal; the pulses, *e.g.*, peas, beans, and lentils; potatoes and roots, such as carrots, parsnips, &c.; sugar and fat of all kinds, together with meat and "offal," will form a satisfactory diet. Many of the more expensive and luxurious foods are superior only in regard to æsthetic qualities.

12. The palatability and digestibility of food are largely dependent upon good cooking, and the nutritive value of much good food is impaired by lack of care and attention in this respect.

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APPENDIX I.

The Composition and Energy Value of certain Food Materials (*see* p. 8).

In this table the figures under the various headings (with the exception of Energy Value) represent percentages of the article in question.

—	Water.	Ash.	Sodium Chloride.	Protein.	Carbohydrate	Fat.	Energy Value, Calories per 1 lb.
Beef.							
Rumpsteak	43·9	0·81	0·06	13·7	—	41·52	2006·3
Silverside	63·4	1·07	0·08	20·01	—	15·26	1016·1
Sirloin	50·0	0·64	0·07	16·16	—	33·14	1748·5
Topside	49·6	0·77	0·06	15·82	—	33·68	1715·1
Kidney	76·3	1·3	0·5	18·1	—	2·6	446·3
Liver	70·8	1·6	0·1	19·9	by diff. 4·4	3·2	587·0
Tripe	81·3	0·23	—	15·75	—	2·12	382·4
Sweetbread	70·8	1·8	0·1	17·0	—	11·0	780·2
Heart	44·5	0·7	0·14	13·16	by diff. 0·48	40·78	1974·1
Tongue	46·8	0·6	0·07	11·89	—	38·64	1851·1
Mutton.							
Leg	51·7	0·82	0·07	16·07	—	28·50	1501·0
Shoulder	45·2	0·76	0·06	13·24	—	34·91	1719·1
Loin	27·8	0·36	0·04	9·47	—	56·57	2562·4
Neck	29·0	0·60	0·05	9·55	—	34·86	1647·9
Pork.							
Leg	50·5	0·7	0·12	16·26	—	11·90	1262·4
Shoulder	37·7	0·5	0·11	15·42	—	27·04	1427·5
Loin	35·0	0·5	0·1	12·94	—	32·60	1615·7
Trotter	—	—	—	14·00	—	10·96	722·6
		Other Ash.					
Bacon.							
Back	24·6	2·3	4·5	9·1	—	59·9	2696·2
Gammon	35·6	2·2	5·9	11·7	—	44·6	2099·3
Streaky	27·0	3·6	4·2	10·3	—	54·2	2478·0
Ham	—	—	—	12·41	—	42·17	2009·9
Tinned Meat	67·2	1·5	—	24·0	—	7·1	745·7
		Ash					
Chicken	33·7	0·57	0·07	12·49	0·08	2·98	359·7
Rabbit (without skin).	—	—	—	12·53	by diff. 0·07	4·5	424·6
					Carbohydrate (Lactose).		
Milk	87·6	0·7	—	3·3	4·8	3·6	303·0
Suet	5·9	0·2	—	1·2	—	93·3	3958·1

—	Water.	Ash.	Sodium Chloride.	Protein.	Carbohydrate.	Fat.	Energy Value, Calories per 1 lb.
FISH (INCLUDING SKIN).							
Herring yearling	46·9	1·04	—	12·1	—	10·95	686·8
Mackerel - -	41·2	0·7	—	11·8	—	7·0	514·8
Salmon (section)	52·9	1·2	—	16·3	—	12·9	847·3
Cod (section) -	70·3	1·1	—	15·7	—	0·1	296·2
Hake - -	53·2	0·8	—	12·4	—	0·6	255·8
Plaice - -	43·6	0·7	—	12·9	—	3·0	366·5
Sole - - -	54·9	1·4	—	15·2	—	1·5	346·1
Turbot - -	45·8	0·6	—	11·1	—	1·5	269·9

—	Water.	Ash.	Fibre.	Protein.	Fat.	Carbohydrate.	Energy Value, Calories per 1 lb.
CEREALS.							
Maize meal -	9·6	0·7	0·3	9·9	2·1	77·4	1712·3
Cornflour - -	11·4	0·1	0·0	0·8	0·1	87·6	1648·4
Oatmeal - -	6·9	1·8	0·8	11·9	8·6	70·0	1886·1
Rice - -	10·9	0·6	0·3	6·7	0·4	81·1	1649·7
Flour - -	11·3	0·8	0·7	10·1	1·6	75·5	1660·0
Tapioca - -	11·9	0·1	0·01	0·2	0·05	87·74	1637·5
Macaroni - -	10·9	0·5	0·1	12·8	0·2	75·5	1650·6
PULSES.							
Beans, haricot -	11·1	3·5	2·6	17·8	0·5	64·5	1551·8
Peas (dried) -	13·8	2·7	5·4	20·4	0·6	57·1	1466·5
Lentils (split) -	12·3	2·1	1·2	20·1	0·4	63·9	1579·0
VEGETABLES.							
Cabbage - -	87·4	1·1	1·3	1·3	0·15	8·7	192·3
Cauliflower -	89·8	1·0	1·3	1·5	0·15	6·3	151·5
Carrots - -	87·0	0·9	1·1	1·2	0·1	9·6	205·0
Onions - -	85·6	0·9	1·1	1·3	0·12	11·1	235·9
Parsnips - -	74·9	1·2	2·3	1·8	0·47	19·4	413·0
Potatoes - -	76·3	0·9	0.5	1·7	0.03	20·6	415·9
Tomatoes -	93·5	0·5	0·7	0·7	0·1	4·5	100·7
Turnips - -	92·4	0·9	0·7	1·4	0·1	4·4	112·0
Green peas(fresh) (as purchased).	78·3	0·7	2·4	3·3	0·2	10·3	261·3
Broad beans (as purchased).	80·0	0·9	1·9	3·5	0·2	13·5	324·8

—	Waste.	Acidity.	Water.	Ash.	Fibre.	Protein.	Total Carbohydrate.	Fat.	Energy Value, Calories per 1 lb.
Apples	9·2	111·7	77·5	0·3	0·7	0·3	9·8	0·2	195·9
Oranges	25·1	90·1	65·1	0·4	0·3	0·6	6·6	0·1	137·4
Bananas	43·3	48·9	40·2	0·5	1·2	0·6	14·1	0·1	278·5
Pears	12·3	33·2	73·9	0·3	1·7	0·3	7·4	0·1	147·0
Plums	5·1	248·7	82·3	0·4	0·8	0·5	7·8	0·3	164·2
Melons	44·7	5·7	51·7	0·2	0·2	0·3	2·6	0·0	54·2

—	Water.	Other Ash.	Sodium Chloride.	Fibre.	Protein	Carbohydrate.		Fat.	Energy Value, Calories per 1 lb.
						Maltose.	Starch by diff.		
Bread (brown)	43·2	1·3	1·0	0·7	7·0	5·8	41·9	0·4	1012·4
Bread (white)	42·3	0·9	0·9	0·5	7·2	3·7	44·4	0·2	1036·9

—	Water.	Sodium Chloride.	Other Ash.	Undetermined.	Protein.	Carbohydrate.	Fat.	Energy Value, Calories per 1 lb.
Butter -	13·85	1·25	0·1	1·4	0·2	—	82·95	3502·9
Margarine -	13·0	1·24	0·4	0·8	0·2	—	84·8	3578·9
Dripping -	—	—	—	—	—	—	100·0	4218·5
Lard - -	—	—	—	—	—	—	100·0	4218·5

—	Water.	Other Ash.	Sodium Chloride.	Protein.	Fat.	Undetermined.	Energy Value, Calories per 1 lb.
CHEESE —							
Hard (full cream)	31·6	2·7	2·0	25·7	35·0	3·1	2011·3
Hard (skin) -	41·5	3·1	2·2	32·2	11·6	9·4	1260·4
Soft - - -	41·1	2·0	1·4	22·1	30·3	3·1	1746·8

—	Water.	Ash.	Fibre.	Protein.	Carbohydrate.		Fat.	Energy Value, Calories per 1 lb.
					Cane Sugar.	Starch, by diff.		
Sugar, brown	0·7	0·1	—	—	98·0	—	—	1822·6
Sugar, white	—	—	—	—	100·0	—	—	1859·8

—	Water.	Ash.	Fibre.	Protein.	Carbohydrate.		Undetermined.	Energy Value, Calories per 1 lb.
					Reducing Hexose as Glucose.	Cane Sugar.		
Syrup, golden.	15·1	0·90	0·0	0·3	44·5	31·9	7·30	1426·6
Honey -	18·3	0·30	0·10	0·4	69·2	2·2	9·50	1290·0
Jam -	26·6	0·40	1·00	0·3	43·9	25·5	2·30	1296·4
Marmalade	27·9	0·17	0·68	0·2	67·0	1·6	2·45	1280·4

——	Water.	Ash.	Protein.	Carbo-hydrate.	Fat.	Undetermined.	Energy Value, Calories per 1 lb.
Eggs (hens')*, with shell.	66·3	1·0	11·1	—	10·12	1·40	659·1

* Average weight of one egg, with shell, is taken as 2 ozs.

APPENDIX 2.

A Simple Typical Diet.

Constituents.	Amount per Day.	Energy Value in Calories.
	Ozs.	
Meat	7	581
Canned meat	2	93
Bread	12	760
Biscuit	3	314
Rice	2	206
Oatmeal	1	118
Bacon	3	465
Butter	1	219
Cheese	1	126
Vegetables { Potatoes	6	180
Vegetables { Cabbage	2	
Jam	3	243
Sugar	2	232
Milk (unsweetened condensed)	1	49
Tea	$\frac{3}{8}$	—
Salt	$\frac{1}{4}$	—
Pepper	1/100	—
Mustard	1/100	—
Pickles	$\frac{1}{2}$	—
		3,586

The above is a simple type of diet which has been proposed for troops not engaged in arduous operations; in practice, variety would be introduced into such a diet by the substitution of articles of approximately equivalent value when available.

APPENDIX 3.

MINERAL CONTENTS, IN MILLIGRAMS PER 100 GRAMS OF THE EDIBLE PORTION OF SOME COMMON FOODS.*

——	Iron.	Calcium.	Magnesium.	Sodium.	Potassium.	Phosphorus.	Chlorine.
Beef, lean -	3·8	8	24	67	35	22	50
Eggs - -	3·0	67	9	15	14	16	100
Milk - -	0·2	120	11	51	142	94	120
Oatmeal -	3·7	93	127	81	380	380	35
Rice, polished	0·7	8	27	21	68	89	50
Wheat flour	1·5	26	30	69	146	86	76
Wheat grain	5·2	44	170	106	515	469	88
Beans, lima, dried.	7·2	71	187	245	1,743	336	25
Cabbage -	0·9	49	14	20	243	27	13
Peas, dried -	5·6	100	145	118	880	397	40
Potatoes -	1·2	11	22	19	440	61	30
Turnips -	0·6	64	169	59	332	51	40
Apples -	0·3	10	8	15	125	13	4
Raisins -	3·6	57	9	141	830	126	70

* Lusk, G.: "The Science of Nutrition" (W. B. Saunders Company, 1919).

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